

Research Article

## Analysis of Stress on Pelton Turbine Blade Due to Jet Impingement

Varun Sharma<sup>^\*</sup> and Sanjeev Kumar Dhama<sup>^</sup>

<sup>^</sup>Rayat-Bahra Institute of Engineering & Bio-Technology, Mohali Campus, Punjab, India.

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### Abstract

The turbine which converts gravitational energy of elevated water into mechanical work is called a pelton wheel impulse turbine. It is a hydro mechanical energy conversion device. This mechanical work is converted into electrical energy by means of running an electrical generator. The kinetic energy of water jet act tangentially on runner of pelton turbine. This runner consist of buckets which are also called as blade so turbine. The shape of blades of pelton turbine consists of splitter profile which splits into two halves such that each turned backward almost through 180° relative to the bucket in horizontal plane. Normally all the jet energy is utilized in propelling the rim of water wheel. This impingement with some force when hits the buckets, it goes through the round periphery in splitter manner. This force produces stress on buckets or turbine blades. Which varies from certain sound value at the place of impingement to the reduced values as water goes outward. In this study of stress analysis on pelton turbine blade is done using Ansys 12.0. In the analysis jet impinges on runner blade of pelton turbine. The stress variations with respect to the geometry of blade are calculated by software itself. The CAD model of blade is made using pro-E software. In it stress calculated by software from tip to end of periphery of runner blade.

**Keywords:** Pelton Turbine, Stress analysis, Jet Impingement, blade deformation

### 1. Introduction

Pelton turbines belong to the family of free jet turbines. A nozzle is placed at the end of the pressure line which converting the potential energy of the water into kinetic energy by forming a water jet. The jet is directed to the runner buckets, the hydraulically active parts of the turbine. At the entrance into the symmetrically shaped buckets the water jet is split into two parts, each developing a sheet of water on the bucket's curved surface. At the end of the working cycle, the water leaves the bucket in the opposite direction of the free jet. The rotational mechanical energy is then transferred through the shaft to the generator which is produced by momentum and pressure of water jet striking the buckets.

Water jet falls with immense pressure on line dividing the two buckets. Jet pressure is controlled by spear which is further controlled by servomotor. Pelton turbine operates at high head (above 10 meters). This runner is further connected with the generator in which the rotor fixed with runner shaft rotates enclosed in between stator. Hence produce electricity.

The pressurized water falls over the inside of blade and it generates stress on throughout section of blade. But the utilization of water jet to produce electricity is less as these turbines works at atmospheric pressure because of which splashing of water occurs makes it difficult to utilize the water jet fully for producing thrust,

so we say these turbines are generally less efficient as compared to reaction turbines. (Bilal Abdullah Nasir *et al*, 2013), (Saurabh Sangal *et al*, 2013).

### 2. Working Principle

Let  $V_j$  = velocity of the jet and  $V_b$  = velocity of bucket

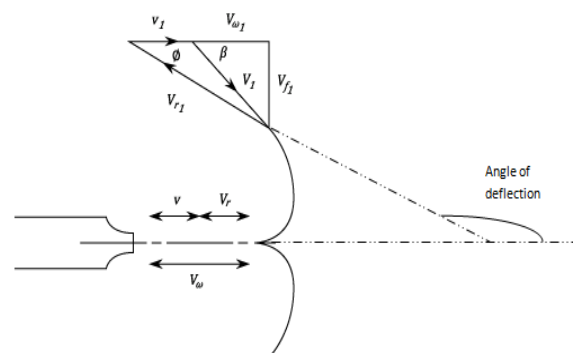


Fig. 1 Water jet hitting bucket

Hence the speed at which jet enters the bucket is given by

$$V_j - V_b$$

The inside of the bucket should be as smooth so as the water does not loose speed at expense of outflow of water. If the jet speed is twice the speed of bucket, then water relative to bucket leaves at speed;

\*Corresponding author **Varun Sharma** is a M.Tech Research scholar and **Sanjeev Kumar Dhama** is working as Asst Prof.

$$V_j - V_b = 2 V_b - V_b = V_b$$

Here the bucket is moving with a velocity  $V_b$  and water coming out of bucket in opposite directions with velocity  $V_b$  that means speed of water coming out relative to housing is nearly zero. (Loice Gdukea et al, 2013; Ignatio Madanhire et al, 2013).



Fig. 2 Pelton turbine runner.



Fig. 3 External stroboscopic view of pelton turbine. (A. Rossetti et al, 2014), (G.Pavesi et al, 2014), (A.Santolin et al, 2014)

### 3. Finite Element Analysis

#### Equivalent stress and strain

The stress is analyzed using ansys 12.0. When the pressure is measured in computed manner it is further analyzed experimentally for various flow angles of jet. Either of these values is to be compared then and error percentage is to be found out. The value of stress is compared according to the von-mises stress criteria, which is considered to be most reliable criteria.

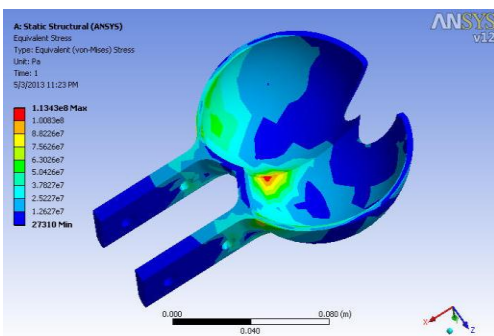


Fig. 4 Stress analysis

The strain analyses is also done in order to check the deformation occurred on the blade. The strain will be shown as

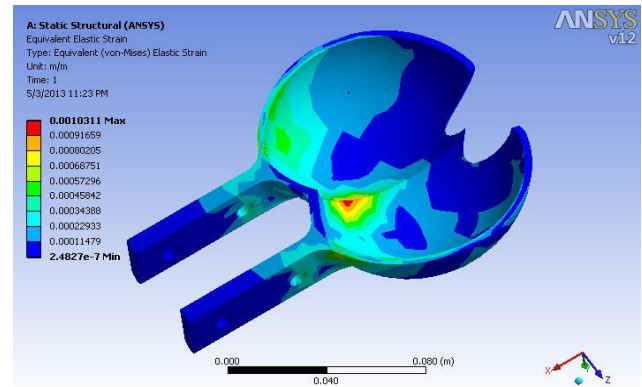


Fig. 5 Strain analysis

The stress verifying from maximum value,  $1.138 \times 10^8$  Pa at  $0^\circ$  position of water jet to 27310 pa , at  $50^\circ$  positions.

We have taken the value of 35 psi as the ideal value kept in hydro electricity generation plants for head above 300 m. which further Equals to  $2.41 \times 10^5$  pa this value comes under the values calculated.

- Hence it proves the Analysis is cultivating right results.
- Strain is shown to calculate the deformation occurred in blade which is under action of continuous force impingement.

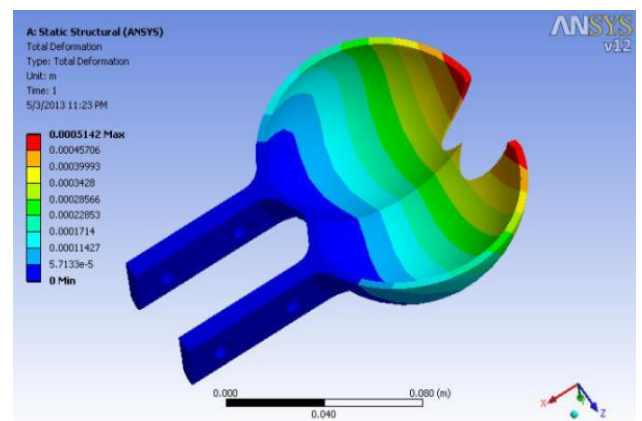


Fig. 6 Total deformation

- The deformation is very minimum 0.0005143 m to 0 m in complete operation. This is the value which varies always because in power plants the water at head above than 300 m , there is a need of dam.
- The silt in water generally brings some hard materials with it since it is a granular material of grain size between sand and clay, which is rock's small parts.
- It when hits the runner blades, produces impact along with the water it create more pressure and rises the risk of corrosion to blade not a desirable thing at all if we talk about life of blades.

- The water is checked when it is in use for impingement. The substance of silt should be lesser than about 5000 ppm, for better life of blades.

**4. Experimental Analysis**

Four pelton buckets with different contours have been designed for the same head and flow rate condition. The buckets named as DB01, DB02, DB03, and DB04 which are casted. The difference between these buckets lies in their profile.

The profile of DB01 is circular on both longitudinal and transverse direction. In the longitudinal section at the middle of one half of the bucket, it has a circular surface of radius 30 mm in the middle transverse section; it is circle of radius 14 mm.

The bucket DB02 is made elliptical section only. The longitudinal section of one half of the section DB02 is an ellipse with axes 52 mm & 29 mm.

Similarly the middle transverse section is an ellipse with axes 58 mm and 29 mm.

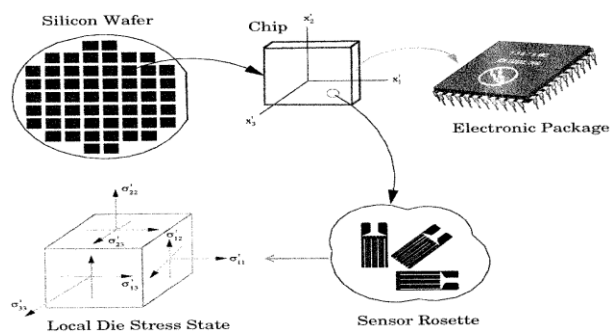
DB03 has combination of elliptical and circular sections. The bucket is elliptical in longitudinal section and circular in transverse section.

DB04 is elliptical in transverse section and circular in longitudinal section. ITDG bucket profile as discussed in Thake (2002). (Thake Jeremy, 2002)

**A. The Sensors**

Sensor is a device which is used to convert mechanical work into electrical signals The sensors which are used to calculate stresses through circuits. The impingement causes thermal expansion of material.

Mechanical loading transmitted via printed circuit board to the package. This develops the three dimensional stresses on the material. (Jeffrey C. suhling et al, 2001; Richard C. Jaeger et al, 2001).



**Fig. 7** Different sensors

**B. Experimentally calculated stress**

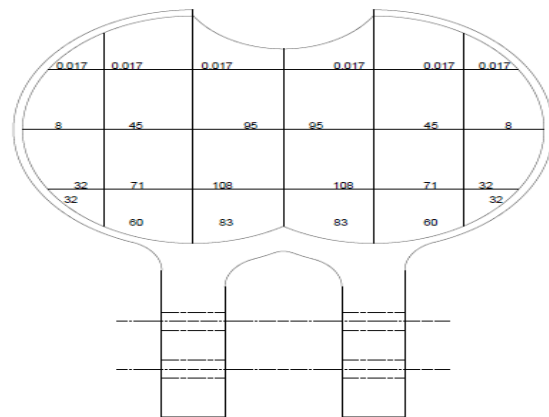
Here the values show the maximum efficient bucket as DB02, so we assumed this to conduct the best experimental analysis. (Binaya K.C et al, 2009; Bhola Thapa et al, 2009).

The value of jet impinges on blade tangentially. When jet is at  $75^\circ$  with the tip of blade maximum thrust can be developed. we take the values computed at  $0^\circ$  and then

experimentally checked them by fixing sensors behind blades. The difference is calculated for finding relative percentage error.

The values shown by finite element analysis are shown in stress v/s column number graph. The different colours showing different values of stresses according to the column position in the blade geometry.

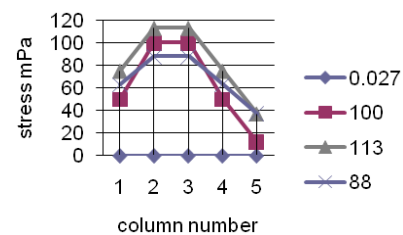
For maximum thrust, the grid is showing different values of stresses experimentally calculated using sensors.



**Fig. 8** Different columns on blade

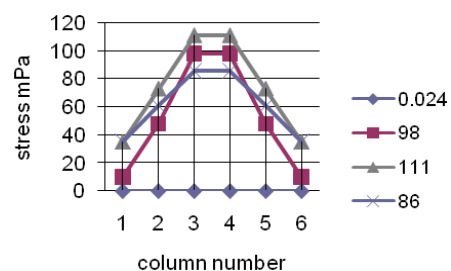
**5. Graphical Views**

The maximum value of stress in this case is 113 MPa. It then starts reducing in magnitude till it reaches its minimum value which is equal to 0.027 MPa, as the water goes outward over the periphery of blade. The jet is at  $0^\circ$  angle here.



**Fig. 9** Analytical graph

The maximum value of stress in this case is 111 MPa. It then starts reducing in magnitude till it reaches its minimum value which is equal to 0.017 MPa, as the water goes outward over the periphery of blade. The jet is at  $50^\circ$  angle here.



**Fig. 10** Experimental graph

### 6. Comparison between Computed and Experimental Data

S No	Computed values	Experimental values	%age Error
Max stress MPa @ 0° angle of jet	113	111	0.05
Min stress MPa @ 50° angle of jet	0.027	0.017	0.03

#### Conclusion

Stress distribution inside the pelton bucket has been analyzed. It can be concluded that stress on turbine blade is reducing as water moves out in its direction of flow along the periphery of pelton turbine blade. At the point where jet impinges maximum stress can be measured. We have observed different values of stress measured computationally corresponding to which maximum stress comes out to be 113 MPa at the point where jet strikes the blade at 0° angle of jet. The minimum value of stress comes 0.027 MPa, at the outermost periphery of blade. When experimentally measured on a model, value of maximum and minimum stresses comes 111 MPa and 0.017 MPa at 0° angle of jet. Comparing to these two values, maximum and minimum stresses in computational and experimental analysis percentage error is calculated which is 0.05 for analytical and 0.03 for experimental result. The wear and tear of the blade depends upon stress which internally produced along with the quality of water.

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